# SYNTHESIZE AND CHARACTERIZATION OF $Al_2O_3$–, $BaTiO_3$–, $TiO_2$–, CuO–CCTO COMPOSITES FOR WIDEBAND DIELECTRIC RESONATOR APPLICATION

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**by**

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## DECLARATION

I hereby declare that I am the sole author of this dissertation. This is a true copy of the dissertation, including any required final revisions, as accepted by my examiners. It has not previously submitted for the basis of the award of any degree or diploma or other similar title of this for any other diploma/examining body or university. I understand that my dissertation maybe made electronically available to the public.

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| | |
|---|---|
| BW% | Percentage of bandwidth |
| DRA | Dielectric resonance antenna |
| EDX | Energy Dispersive X-ray |
| RL | Return loss |
| FESEM | Field Emission Scanning Electron Microscopy |
| XRD | X-ray Diffraction |

## LIST OF SYMBOLS

| | |
|---|---|
| % | Percentage |
| ° | Degree |
| °C | Degree Celsius |
| °C/min | Degree Celsius per minutes |
| MPa | Megapascal |
| λ | Wavelength |
| $\varepsilon_r$ | Dielectric constant |
| tan δ | Tangent loss |

**SINTESIS DAN PENCIRIAN KOMPOSIT $Al_2O_3$–, $BaTiO_3$–, $TiO_2$–, CuO–CCTO UNTUK KEGUNAAN PENYALUN DIELEKTRIK JALUR LEBAR**

## ABSTRAK


Antena logam telah digunakan secara meluas dalam sistem komunikasi tanpa wayar sejak beberapa tahun yang lalu. Secara umum saiz antena yang digunakan adalah besar disamping kehilangan haba (tan δ) yang tinggi dan jalur lebar yang kecil. Kelemahan ini boleh diselesaikan dengan menggunakan bahan seramik dengan pemalar dielektrik ($\varepsilon_r$) yang tinggi dan kehilangan haba yang rendah seperti $CaCu_3Ti_4O_{12}$ **(**CCTO) yang juga dikenali sebagai antena penyalun elektrik (DRA). Pada frekuensi 8 GHz, didapati bahawa $\varepsilon_r$ CCTO ialah 62.76 dan tan δ adalah 0.1458. Ia menghasilkan isyarat antara 8.56-9.12 GHz dengan 6.60% jalur lebar. Tetapi tan δ bagi CCTO adalah tinggi iaitu lebih daripada 0.1 dan liputan jalur lebar kurang daridapa 10% dimana ia tidak mampu meliputi bahagian yang lebih luas dalam sistem komunikasi jalur X (8 GHz hingga 12 GHz). Oleh itu, untuk meningkatkan potensi CCTO sebagai DRA yang lebih baik, bahan oksida yang lain perlu ditambah. Dalam kajian ini, $Al_2O_3$, $BaTiO_3$, $TiO_2$ and CuO telah ditambah daripada 20, 40, 50, 60, dan 80 wt% kepada CCTO. Didapati bahawa $\varepsilon_r$ bagi penambahan $Al_2O_3$ kepada CCTO ialah 37.33 dan tan δ dalam siri komposit ini ditambah baik ke nilai yang lebih rendah iaitu 0.0520. Komposit ini menghasilkan isyarat antara 8.67-9.26 GHz dengan lebar jalur 5.61% (penambahan 20 wt% $Al_2O_3$). Penambahan $BaTiO_3$ telah menigkatkan $\varepsilon_r$ kepada 85.23 dan tan δ dalam siri ini antara 0.0627-0.0258. Hasil kajian menunjukkan komposit ini menghasilkan isyarat antara 9.33-10.21 GHz dengan 8.91% jalur lebar.

Penambahan 50 wt% $TiO_2$ menunjukkan $\varepsilon_r$ berubah kepada 56.47 dan tan $\delta$ dalam siri tersebut antara 0.0165-0.1108. Apabila di uji sebagai antena ia menyalun antara 10.03-11.36 GHz dengan 12.48% jalur lebar. $\varepsilon_r$ yang tinggi iaitu 67.52 diperolehi daripada dengan penambahan 50wt% CuO dan tan $\delta$ antara 0.0203-0.0878 serta menghasilkan isyarat pada julat 9.12-11.29 GHz dengan 21.26% jalur lebar. Semua keputusan ini menunjukkan bahawa semua sampel yang diuji boleh digunakan sebagai antena tetapi siri 50CCTO/50CuO menunjukkan prestasi yang terbaik berbanding dengan siri lain. Atas sebab itu, siri komposit ini seterusnya dioptimumkan dan didapati bahawa siri komposit (50CCTO/50CuO) ini menghasilkan $\varepsilon_r$ yang tinggi iaitu 67.52 dan tan $\delta$ yang rendah (0.0141). Siri komposit ini boleh meliputi julat frekuensi yang lebih luas dalam jalur X dan ia sesuai untuk dijadikan DRA dalam saiz yang lebih kecil dengan prestasi yang lebih baik.

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## ABSTRACT

Metallic antennas have been widely used in wireless communication system. In general this antenna is big in size with high tangent loss (tan δ) and the bandwidth is narrow with low efficiency. These shortcomings can be solved by using ceramic materials with high dielectric constant ($\varepsilon_r$) and low tan δ such as $CaCu_3Ti_4O_{12}$ **(**CCTO), known as dielectric resonator antenna (DRA). At 8 GHz, $\varepsilon_r$ is 62.76 and tan δ is 0.1458 and resonated between 8.56 to 9.12 GHz with 6.6% bandwidth. However, its tan δ is still considered as on the higher side (>0.1) and bandwidth coverage is less than 10% which is not able to cover a wider portion of the X band (8 GHz to 12 GHz) communication system. Therefore, to enhance the properties of DRA, CCTO properties can be modified through the addition with other oxides. In this research, $Al_2O_3$, $BaTiO_3$, $TiO_2$ and CuO, respectively, was added from 20, 40, 50, 60, and 80 wt% into CCTO. It was found that addition of $Al_2O_3$ has reduced $\varepsilon_r$ to 37.33 but has improved tan δ value to the lowest value of 0.0520. This antenna resonated between 8.67 to 9.26 GHz with 5.61% bandwidth (addition 20 wt% $Al_2O_3$). The addition of $BaTiO_3$ has increased $\varepsilon_r$ to 85.23 with addition 80 wt% and tan δ in these series between 0.0627 – 0.0258. The result shows these composites resonated between 9.33 to 10.21 GHz with 8.91% bandwidth. The addition of 50 wt% of $TiO_2$ shows $\varepsilon_r$ of 56.47 and tan δ of these composites between 0.0165-0.1108, resonated from 10.03 to 11.36 GHz with 12.48% bandwidth. The highest $\varepsilon_r$ (67.52) was obtained from 50 wt%